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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/007,304	12/05/2001	Ki-Bum Kim	ASMMC.033AUS	2193

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EXAMINER

RAO, SHRINIVAS H

ART UNIT	PAPER NUMBER
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2814

DATE MAILED: 02/12/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

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Office Action Summary	Application No.	Applicant(s)	
	10/007,304	KIM ET AL.	
	Examiner	Art Unit	
	Steven H. Rao	2814	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 17 November 2003.
- 2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 35-37, 39-41 and 43-58 is/are pending in the application.
- 4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) ☐ Claim(s) _____ is/are allowed.
- 6) ☐ Claim(s) 35-37, 39-41 and 43-58 is/are rejected.
- 7) ☐ Claim(s) _____ is/are objected to.
- 8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
 Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
 Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
 - a) ☒ All b) ☐ Some * c) ☐ None of:
 - 1. ☒ Certified copies of the priority documents have been received.
 - 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 - 3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).
- * See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- | | |
|---|---|
| 1) <input type="checkbox"/> Notice of References Cited (PTO-892) | 4) <input type="checkbox"/> Interview Summary (PTO-413) |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948) | Paper No(s)/Mail Date. _____ |
| 3) <input type="checkbox"/> Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) | 5) <input type="checkbox"/> Notice of Informal Patent Application (PTO-152) |
| Paper No(s)/Mail Date _____ | 6) <input type="checkbox"/> Other: _____ |

DETAILED ACTION

Priority

Receipt is acknowledged of paper submitted under 37 CFR 1.114, claiming priority from U.S. Serial No. 10, 007304 filed December 05, 2001 which itself claims priority from Korean Patent Application No. 2000-0074025 filed on December 06, 2000 papers have been placed of record in the file.

Request for Continued Examination

The request filed on 11/17/2003 for a Request for Continued Examination (RCE) under 37 CFR 1.114 based on parent Application No. 109/007304 is acceptable and a RCE has been established. An action on the RCE follows.

Preliminary Amendment Status

Acknowledgment is made of entry of amendment filed 11/17 / 2003 are currently pending in the Application.

Therefore claims 35-37,39-41 and 43-58 as recited in the amendment of 11/17/ 2003 are currently pending in the Application.

Claims 1-34, 38 and 42 were cancelled by the Supplemental amendment of August 08, 2003.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

Claims 35-37,39-42 and 45 , 52-54are rejected under 35 U.S.C. 102(e) as being anticipated by McTerr.(U.S. Patent No. 6,204,179, herein after McTerr)

With respect to claim 35, McTerr discloses a diffusion barrier for a copper interconnect comprising layer of metal nitride [McTerr fig. 2 # 4, col. 17 lines 64 which describe a barrier layer “ may be any metal nitride and includes tantalum nitride (TaN) , titanium nitride (TiN), tungsten nitride (Wn) and a Titanium aluminum nitride (Ti_xAl_yN_z)] directly contacting and covered by a layer of reactive metal different from a metal in the nitride layer (McTerr fig. 3 , col. 18 lines 12-15, describing an wetting aluminum layer (not shown in the drawings) which is a different metal from Ti, Ta, W and identical to the TiN and Aluminum layers described in at least the preferred embodiments of the present application page 3, paras 10-13), wherein the grain boundaries of the metal nitride layer are stuffed with a metal compound of the reactive metal. (McTerr col. 17 lines 45 to 55) wherein the reactive metal is different metal from

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each metal in the metal nitride and is selected from the group consisting of Al, Si, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mg, Y and La. (McTerr col. 18 line 48-49) and wherein the diffusion barrier directly underlies a copper layer of the copper interconnect. (McTerr fig.2 # 4. col. 17 line 64) .

.With respect to claims 36 and 37, wherein the metal nitride layer is selected from the group consisting of titanium nitride, tungsten nitride and tantalum nitride. (McTerr col. 17 lines 63-65)

With respect to claims 39-41, wherein the reactive metal is selected from the group consisting of Al, Si, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mg, Y and La. (McTerr col. 18 line 48-49)

With respect to claim 45 wherein the different metal compound is a nitride of the reactive metal. (McTerr col. 15 line 3)

With respect to claim 46 wherein the different metal compound is selected from the group consisting of aluminum nitride and silicon nitride (McTerr col. 15 line 3).

With respect to claim 47 (not presently amended) wherein the metal nitride layer is about 5 to 10 nm thick. (McTerr col.18 line 3).

With respect to claim 48 wherein the reactive metal layer is about 2 nm thick. (McTerr col. 18 line 8).

With respect to claim 49, additionally comprising of a second layer of metal nitride over the layer of reactive metal. (McTerr fig. 9 and col. 15 lines 12 to 25).

With respect to claim 50, McTerr discloses a diffusion barrier for a copper in a interconnect comprising : a first metal layer of metal nitride (McTerr fig. 2 # 4, col. 17

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line 64) , a layer of reactive metal layer directly contacting and over the first layer of metal nitride (McTerr fig. 2 # 5, col. 18 lines 3-4) wherein the reactive metal is selected from the group consisting of metals of group III B of the periodic table, metals of group IV B of the periodic table, metals of group V B of the periodic table and metals of group VI B of the periodic table (see rejection of claim 35 above and this claim is rejected for the same reasons)and a second layer of metal nitride directly contacting and over the layer of reactive metal, wherein the grain boundaries of the first and second metal nitride layers are stuffed with a different metal compound. And the second layer of metal nitride underlies and contacts a copper layer of the copper inter connect (McTerr fig. 9 and col. 15 lines 12 to 25 and see rejection of claim 35 above and this claim is rejected for the same reasons).

With respect to claim 51, wherein the different metal compound is selected from the group consisting of an oxide of the reactive metal and a nitride of the reactive metal. (McTerr col. 15 line 3).

With respect to claim 52, wherein the layer of titanium nitride covered by a layer of aluminum, wherein the grain boundaries of titanium nitride layer are stuffed with aluminum oxide. (McTerr col. 17 lines 40 to 57).

With respect to claim 54, wherein the diffusion barrier additionally comprising a second layer of titanium nitride between the aluminum layer and the copper filler. (McTerr fig. 9 and col. 15 lines 12 to 25).

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

A. Claims 43, 44 and 55-58 are rejected under 35 U.S.C. 103(a) as being unpatentable over McTeer et al. (U.S. Patent No. 6,204,179 herein after McTeer as applied to claims above and further in view of Aoyama et al. (U.S. Patent No. 5,592,024, herein after Aoyama).

With respect to claim 43 (not presently amended) wherein the different metal compound is an oxide of the reactive metal.

McTarr describes a reactive metal but does not specifically mention an oxide of the reactive metal.

However, Aoyama in column 19 lines 39-57 describes the use of silicon dioxide as an upper interlayer insulating film in three/four wiring layer structures to form interlayer insulators at temperatures lower than the melting point of the already formed metal lines.

Therefore it would have been obvious to one of ordinary skill in the art at the time of the invention to include Aoyama's silicon dioxide as an upper interlayer insulating film in three/four wiring layer structures to form interlayer insulators at temperatures lower than the melting point of the already formed metal lines. (Aoyama col. 19 lines 39-57).

With respect to claim 44 wherein the different metal compound is selected from the group consisting of aluminum oxide and silicon oxide. (Aoyama col. 19 lines 39-57).

With respect to claim 55, wherein the layer of metal nitride directly contacting and covered by a layer of silicon, wherein the grain boundaries of the metal nitride layer are stuffed with silicon oxide and diffusion barrier directly underlies a copper layer of the copper interconnect. (Aoyama col. 19 lines 39-57 and see rejection of claim 35 above and this claim is rejected for the same reasons).

With respect to claim 56, wherein the layer of metal nitride comprises titanium nitride. (McTarr col. 17 line 64).

With respect to claim 57, additionally comprising a second layer of metal nitride over the layer of silicon. (McTarr fig. 9 and col. 15 lines 12 to 25).

With respect to claim 58, wherein the second layer of metal nitride comprises of titanium nitride. (McTarr col. 15 lines 12 to 25).

B. Claim 53 is rejected under 35 U.S.C. 103(a) as being unpatentable over McTarr (U.S. Patent No. 6,204,179 herein after McTarr as applied to claims above and further in view of Aoyama et al. (U.S. Patent No. 5,592,024, herein after Aoyama) and further in view of Dutta (U.S. Pre grant Publication No. 2002/ 64592, herein after Dutta).

With respect to claim 53, (not presently amended) wherein the layer of titanium oxide is deposited by atomic layer deposition (ALD).

McTarr and Aoyama describes several method of dry deposition like CVD PECVD, but do not specifically describe ALD.

However, Dutta in col. 3 lines 1-2 describes several dry methods including ALD to have more precise control during the deposition of thinner layers and form a thin layer of better quality than by other dry methods.

Therefore it would have been obvious to one of ordinary skill in the art at the time of the invention to include Dutta's Atomic layer deposition method instead of Lai and Aoyama's dry methods like CVD to have more precise control during the deposition of thinner layers and form a thin layer of better quality than by other dry methods.

Response to Arguments

Applicant's arguments filed on August 04, 2003 have been fully considered but they are not persuasive for the following reasons :

First all the presently recited limitations of pending claims are taught/ suggested by the applied references as shown above.

Secondly Applicants' attempt to limit the teachings of McTeer to barrier layer only of Ti_xAl_y and N_z is not persuasive because McTeer describes in col. 17 lines 62 to 66 (reproduced below) describes several metal nitride layers including any metal nitride layer , and this includes other metal nitride than the metal in the reactive metal layer .

FIG. 2 shows a cross-section of an insulating layer 1 of a silicon substrate having an opening which is overlaid with a 60 copper diffusion barrier layer 4 which is then overlaid with aluminum wetting layer 5. The copper diffusion barrier layer 4 may be any metal nitride and includes tantalum nitride (TaN), titanium nitride (TiN), tungsten nitride (WN) and a titanium aluminum nitride ($Ti_xAl_yN_z$) having the atomic 65 composition described above in the description of FIG. 1 being preferred. The copper diffusion barrier layer 4 is

Therefore when a Barrier layer of TaN, TiN, WN are formed by McTeer as described above and an Aluminum layer is formed thereon (McTeer fig. 3 , col. 18 lines

12-15, describing an wetting aluminum layer (not shown in the drawings) which is a different metal from Ti, Ta, W and identical to the TiN and Aluminum layers described in at least the preferred embodiments of the present application page 3, paras 10-13 .

Therefore McTerr describes/ teaches, " particular metal nitride in the layer " (any metal nitride layer, TaN, TiN and WN identical to Applicants' preferred embodiments), " of a structure comprising grain boundaries " (McTeer col. 1 lines 4764, col. 2 lines 20-267, col. 3 lines 15-20) and " of a composition of a different metal compound that could stuff grain boundaries "(McTeer col. 15 line 3, col. 17 lines 40-57, col. 18 lines 48-49, reactive metal Al, Co, Ni which are different from Ti, Ta and W).

Applicants' attempt to limit McTeer's teaches to a barrier layer only of $Ti_xAl_yN_z$ is not supported by the teachings of McTeer which as shown above includes several specific metal nitride layers including any metal nitride layer.

Applicants' arguments based on the assumption that McTeer 's allegedly fails to , " explicit (ly) teaching or suggestion of stuffed grain boundaries " therefore the Examiner's rejection relies on inherency is at odds with McTerr's teachings at least in col. 15 line 3, col. 17 lines 40-57, col. 18 lines 48-49). Wherein McTerr teachings reactions similar to Applicants' preferred embodiment which results in stuffed grain boundaries.

It is noted for the record that The Examiner relied on a single first embodiment of McTeer as partially shown in figures 1-6 and described . in various cols. and lines stated above. In this single embodiment , McTerr in col. Col. 2 lines 64, etc. describes a

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barrier layer of any metal nitride including TaN, TiN, Wn and $Ti_x Al_y N_z$ over which an Aluminum wetting layer 5 is deposited (col. 18 lines 1-5) .

Applicants' argument that in McTerra's oxidation reaction of $Ti_x Al_y N_z$ " some nitrogen in the $Ti_x Al_y N_z$ compound is replaced with oxygen and therefore the resulting $Ti_x Al_y N_z O_m$ that does not stuff the grain boundaries of a metal nitride is completely at odds with McTerra's disclosure for the following reasons : When TiN is used by McTerra a reaction similar to that described by Applicants' in their specification (admitted by the Applicants' to be well known prior art method) page 6 para 3 :

" In case of TiN diffusion barriers, commonly used in aluminum metallization, one method to improve the barrier properties is to stuff the grain boundaries with extra oxygen by annealing a TiN thin film deposited by PVD or CVD in a N_2 or O_2 ambient . For example, diffused oxygen in the grain boundaries of TiN reacts to form titanium oxide that is thought to stuff grain boundaries."

Therefore it is the metal component of the $Ti_x Al_y N_z$ compound like Titanium , Aluminum that reacts with the Oxygen during the oxidation to produce the metal oxide that stuffs the boundaries and the argument that some nitrogen in the $Ti_x Al_y N_z$ compound is replaced with oxygen and therefore the resulting $Ti_x Al_y N_z O_m$ does not stuff the grain boundaries of a metal nitride is irrelevant to the step of stuffing the boundary.

Further Applicants' claims(1, ,50,55 etc.) and specification (page 7 para 0037) explicitly state that, " A shown in the table 2, metal such as Al, Zr, Cr, V, Nb, HF and TA

that have an enthalpy of oxide formation larger than that of Ti oxide can form oxides by reacting with oxygen atoms to bond to Ti as they diffuse along the TiN grain boundaries. Consequently, these metals can be used to stuff the grain boundary."

Therefore when $Ti_xAl_yN_z$ compound is oxidized it will be the metal namely Al and Ti thereof that will react with the oxygen to form oxides that will stuff the grain boundaries (as also taught by Applicants' specification) and whether or not some of the oxygen reacts with the oxygen is irrelevant to metal oxide formation that diffuses to stuff the grain boundary.

Applicants' arguments based on the alleged combination of different embodiments (assuming arguendo to be true) is not persuasive because it is very clear from McTear's description in the summary of the invention section that different embodiments have most steps that are common and interchangeably used and therefore the alleged 103 rejection instead of a 102 with respect to claim 35 also fails because McTear describes most steps in different embodiments are common and interchangeably used (as shown above) and further McTear also shows/ describes every limitation of presently recited claim 35 is described by McTear thus the requirements of the 102 rejection is satisfied.

It should be noted that when McTear teaches barrier layers of alternative materials like (any metal nitride layer, TaN, TiN and WN, etc.) and McTear describes its processing steps using TiAlN (as an example) being doped with oxygen/ oxygen species it is very clear that when other metal nitride like any metal nitride, TaN, TiN or

Wn is used in the place of the TiAlN layer the same processing steps including dopeing with oxygen/ oxygen species of the other metal nitride like any metal nitride, TaN, TiN or Wn has to occur.

Applicants' arguments that McTeer's teachings can be distinguished because McTeer teaches only using Al as a wetting layer, assuming Applicants' argument is true, is not consumarate with the presently recited claims which recite "a metal selected from the group consisting of Al (aluminum) , SI ..".

Therefore all the presently recited limitations of claim 35 are taught by McTeer and the previous 102 (e) rejection is maintained.

Claims 36-37, 39-41 and 45-49 were alleged to be allowable because they depend upon rejected claim 35, however as shown above claim 35 is not allowable and therefore claims 36-37, 39-41 and 45-49 are also not allowable.

Claims 43-44, were alleged to be allowable because of their dependency upon allegedly allowable claim 35 and claims 55 and 56-58 were alleged to be allowable because of the reasons for allegedly allowing claim 35, however as shown above claim 35 is not allowable and therefore claims 43-44 and 55, 56-58 are also not allowable.

Claim 53 was alleged to be allowable because of their dependency upon allegedly allowable claim 52, however ashown calim 52 is not allowable therefore claim 53 is also not allowable.

Thirdly , McTERR teaches the barrier layer is overlaid with an Aluminum wetting layer (col. 18 line 3) that reacts to form an alloy with an overlying copper layer (col. 18 lines 15-18) .

barrier layer 4. The aluminum wetting layer 5 is deposited using PVD or CVD techniques well known to one of ordinary skill in the art and is deposited to a thickness of approximately 50 Å to approximately 500 Å, with approximately 200 Å being preferred.

above in the description of FIG. 1. Upon filling with copper, annealing and reflow, the aluminum wetting layer 5 is consumed thereby forming a Cu_nAl alloy layer 6 wherein n is an integer from about 0.5 to about 4. The Cu_nAl alloy layer 6 has a lower melting point (i.e., 450° C.) than elemental copper (i.e., 1000° C.), thus making it easier for the copper to flow into the opening. Although depicted as a total consumption of the aluminum wetting layer 5, it is to be understood that total consumption of aluminum wetting layer 5 may not occur upon the deposition of copper 3, annealing and reflow steps, and that some aluminum which is not in the form of a Cu_nAl alloy may be present in the layer which is depicted as the Cu_nAl alloy layer 6.

Fourthly , McTERR teaches its metal nitrides has grain boundaries that are stuffed with a metal compound of the reactive metal because McTERR teaches similar process as described in application specification page 6 (Para 0033) lines 8 to 13 etc. subtitled “ a method of stuffing” using the same materials for the same purposes and what is true for Applicants’ is also true for the McTERR reference i.e. McTERR’s metal nitrides has its grain boundaries that are stuffed with a metal compound of the reactive metal.

Applicants’ argument regarding inherency is not persuasive because Applicants’ specification states that the preferred embodiment (indeed the only embodiment) states that the similar process with same materials for the same purpose Always produces the stuffing and this is also true for the McTERR reference.

Any inquiry concerning this communication or earlier communication from the examiner should be directed to Steven H. Rao whose telephone number is (571) 272-

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1718.. The examiner can normally be reached on Monday- Friday from approximately 7:00 a.m. to 5:30 p.m.

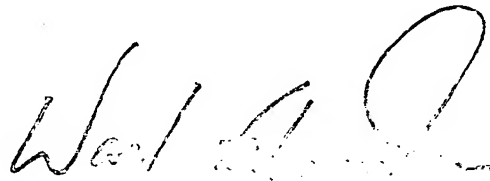
Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 308-0956. The Group facsimile number is (703) 308-7724.



Steven H. Rao

Patent Examiner

August 09, 2003.



SUPERVISOR
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